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Identification of managerial shaping factors in a petrochemical plant by resilience engineering and data envelopment analysis

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ABSTRACT

Resilience engineering (RE) is a novel approach that is capable of controlling and limiting incidents and accidents. This study identifies managerial shaping factors in a petrochemical plant by RE and data envelopment analysis (DEA). To do this, a standard questionnaire containing resilient factors is completed by managers of a petrochemical plant. Then, the best DEA model is selected based on average efficiency and statistical test. In addition, sensitivity analysis are performed to identify the most important shaping factors. Reporting culture, management commitment, and preparedness are identified as the most important factors in this paper, respectively. Finally, the proposed model is validated and verified through statistical experiment. The proposed approach would help managers to have a comprehensive understanding of the plant with respect to the RE. To the best of our knowledge this is the first paper that examines resilient shaping factors in a petrochemical plant with respect to management and organization by DEA.

Motivation and significance

Resilience engineering (RE) is a new concept for safety improvement of complex systems such as petrochemical plants. The related literature reveals that there are only few studies available in which managerial aspects of resilience engineering is evaluated by quantitative methods. Moreover, DEA has not been used for managerial aspects of resilience engineering in petrochemical plants. In addition, management and organizational aspects of resilience engineering have significant impacts for safety and reliability of petrochemical plants. Improved decision-making process will be available by considering and modeling managerial resilience factors through a robust mathematical modeling approach. Weights of each factor are usually obtained based on expert opinion in previous studies. It is therefore quite essential to apply an accurate mathematical model to calculate weights of each factor. This is shown for the real petrochemical plant of this study.

1. Introduction

Resilience engineering (RE) is a novel approach that is capable of controlling and limiting incidents and accidents. In the recent decades, humankind has encountered major challenges. Most of them are directly or indirectly related to what is called “the environment”. Even many social problems have their roots in environmental problems (Qureshi, 2007). In order to solve complex problems of technological systems, researchers have widely used resilience engineering (RE) in different industrial environment because it illustrates a new approach of thinking about safety problems. RE has been developed to address the new concerns of safety that arise from the use of increasingly complex socio-technical systems. Herein, performance depends on tightly coupled social and technical functions (Steen and Aven, 2011). Moreover, RE, by its nature, has strong links with human factors, control theory, and safety engineering. It provides a way to address the issues of emergent accidents and the often-disproportionate consequences. In the field of safety management, RE has been investigated as a new area (Nemeth et al., 2009). RE is a paradigm for safety management that focuses on how to help people to acquire foresight and to predict different kinds of risks in order to

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address the complexities under pressure (Haimes, 2009). In other words, RE puts an emphasis towards success; how people, systems, and organizations learn and adapt themselves, and thus create safety in an environment with hazards, tradeoffs, and multiple goals (Hollnagel et al., 2006). Definitely, this approach is beyond the ability to continue functioning in the presence of stress and disturbances; therefore, it can be considered as a key idea in many industries (Dekker, 2006).

Recently, some studies have considered RE as a strategic concept dealing with the improvement of complex systems such as nuclear power plant (Carvalho et al., 2008), healthcare systems (Jeffcott et al., 2009), aviation (Dekker et al., 2008; Gomes et al., 2009), heavy rains forecast (Dolif et al., 2013), process industry (Shirali et al., 2013), adaptive management (Park et al., 2013), industrial processes (Dinh et al., 2012), and petrochemical plants (Azadeh et al., 2013; Azadeh and Salehi, 2014; Azadeh et al., 2014c, d; Vugrin et al., 2011).

This study identifies managerial shaping factors in a petrochemical plant by RE and DEA. DEA has many applications in various fields of industry and this approach is an efficient and widely used method for performance assessment. The related literature reveals that there are only few studies available in which managerial aspects of resilience engineering is evaluated by quantitative methods. Moreover, DEA has not been used for managerial aspects of resilience engineering in petrochemical plants. Therefore, DEA model is applied for evaluating and identifying managerial shaping factors in a real petrochemical plant in this study. In addition, weights of each factor are usually obtained based on expert opinion in previous studies. It is therefore quite essential to apply an accurate mathematical model to calculate weights of each factor.

The main objective of this study is to attain more realistic results for decision makers in the field of RE through DEA method. Management commitment, learning culture, reporting culture, awareness, preparedness and flexibility are key factors introduced by Hollnagel et al. (2007) to assess RE in organizations and industries. This study considers all six factors that have been introduced Hollnagel et al. (2007).

The proposed approach would help managers to have a comprehensive understanding of the petrochemical plant with respect to the RE. To the best of our knowledge this is the first paper that examines resilient shaping factors in a petrochemical plant with respect to management and organization by DEA. The remainder of this paper is structured as follows: after the Introduction Section, Section 2 focuses on the RE concept and the relevant studies. Methodology is described in Section 3. Thereafter, experiment and results are presented in Section 4. Finally, the paper is concluded in Section 5.

2. Resilience engineering

The capability of an organization or system to preserve a stable state in the risky environment can be introduced as definition of RE. Wreathall (2006) defined RE as "The capability of an organization (system) to preserve or recover quickly to a stable state, allowing it to continue operating during and after a major mishap or in the presence of continuous significant stresses" (Wreathall, 2006).

The factors identified in the literature review for RE concept are preparedness, reporting culture, learning culture, awareness, management commitment, and flexibility. Each of these factors has a special meaning in different application fields. By customizing each of them for a special field, we can identify the potential sources of data for evaluation of performance within organization or system (Wreathall, 2006).

The six factors in a resilient system or organization can be defined as following (Wreathall, 2006):

- Management commitment: Top executives and managers identify issues and problems related to the human performance to take appropriate decisions to eliminate or limit them.
- Reporting culture: It will also bring the certainty that people understand the short message processes.
- Learning culture: RE emphasizes learning from all events including accidents, incidents, analysis of normal work etc.
- Awareness: Managers are able to recognize employees' performance based on data collected from a plant. In addition, all staff should be aware of the ongoing status of resilience in the system.
- Preparedness: The organization or system continuously anticipates the problems of human performance in the plant and gets prepared to handle them.
- Flexibility: Flexibility is often a key factor to cope with the problems in the system. It is the ability of the system or organization to adapt to any kind of problems in order to maximize the capability of the system to solve the problems without failure in system activities.

Considerable efforts have been made in the recent years to specify basic features of resilient organizations or systems. Moreover, extensive pieces of research have been carried out to develop appropriate concepts, principles, percepts and methods which can provide the basic building blocks of the RE framework (Steen and Aven, 2011).

3. Methodology

In this study, managerial shaping factors are identified in a petrochemical plant by RE and DEA. Improved decision-making process will be available by considering and modeling managerial resilience factors through a robust mathematical modeling approach. Fig. 1 presents a schematic view of this approach. In summary, the proposed approach is achieved as follows:

Step 1: A standard questionnaire has been designed by considering the RE factors to performance evaluating.
Step 2: Perform content validity test. If the results are acceptable, go to step 2. Otherwise, go back to step 1.
Step 3: Gather necessary data. Managers must complete standard questionnaire.
Step 4: Perform reliability test. If the results are acceptable, go to step 5. Otherwise, go back to step 3.
Step 5: Apply different DEA models by considering management commitment, learning culture, reporting culture, awareness, preparedness, and flexibility as outputs and one dummy input. Managers of a petrochemical plant are considered as decision-making units (DMUs).
Step 6: Select the best DEA model based on higher value for average efficiency.
Step 7: Identify efficient DMU according to efficiency and results of DEA model.
Step 8: Results of selected DEA model must be validated and verification statistical experiment
Step 9: Perform sensitivity analysis. To do this, run DEA model by omitting indicators separately.